Supply Chain Contracting Forecast for U.S. Offshore Wind Power – The Updated and Expanded 2021 Edition

A Report by
The Special Initiative on Offshore Wind

October 2021

ABOUT THE SPECIAL INITIATIVE ON OFFSHORE WIND

The Special Initiative on Offshore Wind (SIOW) is an independent organization, generating fact-based research and convening multi-sector collaboration to provide expertise, analysis, information sharing, and strategic partnerships with industry, advocacy, and government stakeholders. We do this with a goal of driving the responsible and sustainable deployment of offshore wind in the U.S.

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PARTNERS

SIOW releases this report with review by and the support of our partners organizations in this work: the American Clean Power Association, the Business Network for Offshore Wind, the National Offshore Wind Research and Development Consortium, and the National Ocean Industries Association.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

BOEM	Bureau of Ocean Energy Management
CAPEX	Capital Expenditure
COP	Construction and Operations Plan
DEVEX	Development Expenditure
EPCI	Engineering, Procurement, Construction, and Installation
GW	Gigawatt
LCOE	Levelized Cost of Energy
MW	Megawatt
OPEX	Operational Expenditure
OREC	Offshore Renewable Energy Credit
PPA	Power Purchase Agreement
RCG	Renewables Consulting Group
RFP	Request for Proposal
RPS	Renewable Portfolio Standard
SIOW	Special Initiative on Offshore Wind
TOTEX	Total Expenditure
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

America's growing offshore wind power industry – now with a national target of generating 30 GW of clean, cost-effective power by 2030 – presents a $109 billion revenue opportunity to businesses in the offshore wind power supply chain over the course of the next decade. These expenditures include making investments in the development, construction, and operational phases in the offshore wind sector, also known as total expenditures, or TOTEX.

In this report, the Special Initiative on Offshore Wind (SIOW) quantifies the extensive supply chain business opportunities this $109 billion TOTEX is creating to build out the U.S. offshore wind sector between now and 2030, with quantification broken down by offshore wind farm component, state, and year through 2030.

This is an updated analysis of the 2019 version of the report SIOW released and similarly offers a road map on the timing and pace of power and supply chain contracting prospects for U.S. offshore wind power suppliers and vendors. It also provides an overview for states looking to attract supply chain facilities and build necessary infrastructure for offshore wind industry development.

The 2019 analysis only included a forecast of capital expenditures (CAPEX) associated with the U.S. offshore wind sector. In this 2021 version, we expand our analysis to include both development expenditures (DEVEX) and operational expenditures (OPEX), offering a more complete perspective of the opportunity of this massive supply chain. In addition, we increase the offshore wind development target from 18.6 GW to 30 GW by 2030 to reflect the new and expanded offshore wind national target.

There are a multitude of components that are required to build out the offshore wind sector's supply chain. Key industry components required to achieve a $109 billion utility-scale build-out of 30 GW of capacity by 2030 include:

More than 2,057 offshore wind turbines & towers ....$43.9 billion
More than 2,110 offshore turbine & substation foundations.......$17.0 billion
More than 8,000 kilometers of export & array cables ....$12.9 billion
More than 53 offshore & onshore substations............................$10.3 billion
Other CAPEX[1] ……………………………………………………………………….$16.0 billion
Development Expenditure (DEVEX)……………………………………….$6.16 billion
Operational Expenditure (OPEX)…………………………………………… $2.83 billion
Total Expenditure (TOTEX)…………………………………………………..$109 billion

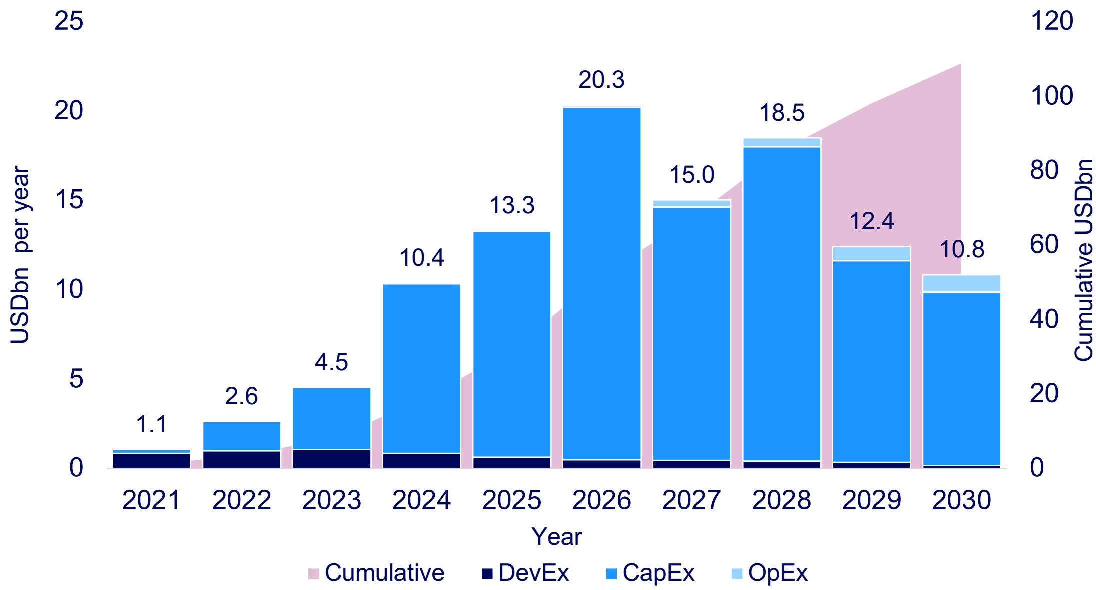
Note that these estimates are conservative. Additional public and private expenditures are not captured in this report, including investments in local fabrication facilities and port infrastructure projects, construction of vessels needed specifically for offshore wind

[1] This category includes contingency, project management, insurance, legal and financing fees, contracting costs, and other miscellaneous project costs.

construction, grid upgrade costs onshore, interconnection fees, lease acquisition costs, or any operating lease or grid fees.

This forecast only accounts for the spending associated with the 32 GW of project that will take place before 2030. In the years following 2030, there will be a large portion of the OPEX spend continuing as the projects begin to enter operation and some of the CAPEX spend will continue as some of the projects continue their construction.

Figure 1:
U.S. Offshore Wind Annual and Cumulative TOTEX Activity by Sub-category

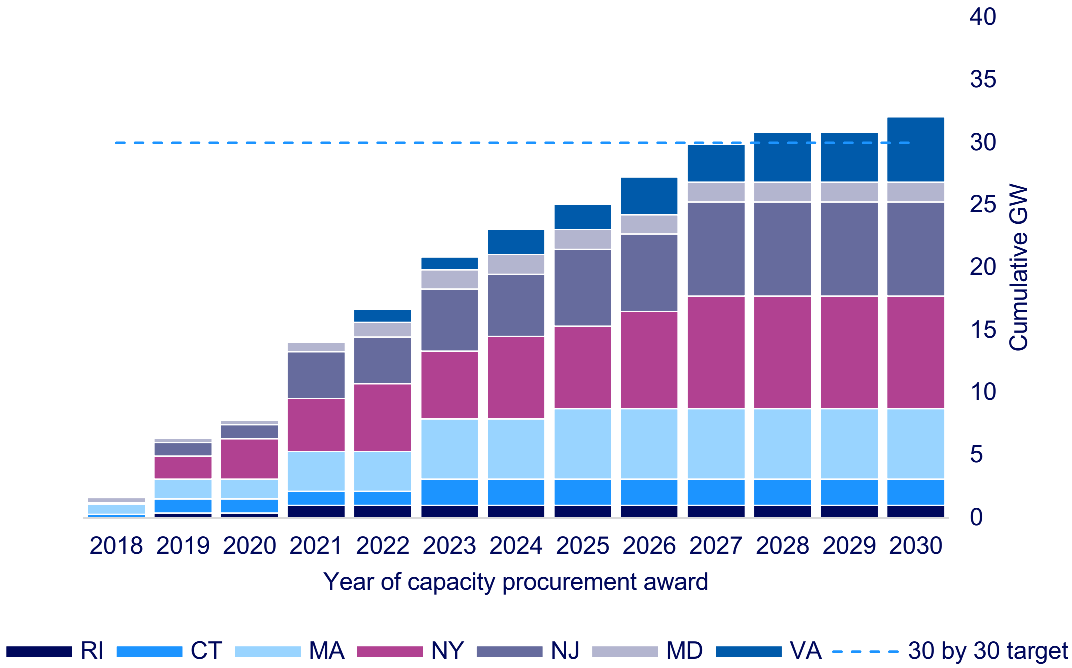


This report also provides forecasts of state offshore wind power procurements through 2030. Market visibility is rising due to state commitments which is driving sustained industry momentum and will generate economies of scale. This analysis has assumed each state will procure the capacity listed below by 2030.

New Jersey.. 7,558 MW
New York .... 9,314 MW
Massachusetts .... 5,604 MW
Connecticut... 2,108 MW
Rhode Island .... 1,000 MW
Maryland .... 1,568 MW
Virginia .... 5,200 MW

TOTAL by 2030: 32,352 MW

Figure 2:
Offshore Wind Procurement Forecast 2018 – 2030



Taken together, these state commitments amount to 32,062 MW of offshore wind power and represent a total investment of nearly $109 billion that will require a significant number of suppliers from many states around the country. These are all the commitments needed to meet – and exceed – the nation's 30 GW goal. It should be noted that states that have targets for offshore development but do not yet have procurements mandates – as is the case for North Carolina, California, and Maine – are not included in this analysis.

This SIOW report offers a new and more complete view of what this massive construction effort will mean for companies that are needed to meet the demands of this growing industry. For states, it is also an indicator of the sizeable volume of components needed to meet the state's goal and the pace of offshore wind power procurements, and highlights the tremendous economic opportunity, particularly as the nation looks to rebound from the sharp economic impacts of the COVID-19 pandemic. As states work to secure supply chain facilities, the forecasts presented here have implications for timing offshore wind industry infrastructure development and supply chain incentives.

BACKGROUND

The U.S. offshore wind power sector is well underway. In 2016, the nation's first offshore wind farm was commissioned off Block Island, Rhode Island (30 MW) and the Coastal Virginia Offshore Wind project was commissioned in 2020 (12 MW). Today, offshore wind farms totaling 8,894 MW are currently contracted to provide electricity in Massachusetts (1,604), Connecticut (1,108), New York (4,314), Maryland (368), Rhode Island (400), and New Jersey (1,100). In New Jersey, two projects have been announced as winners of the second round of offshore wind solicitation for another 2,658 MW of development. Massachusetts and Maryland are in the process of reviewing bids submitted by developers and are expected to award up to 1,600 MW in Massachusetts and procure a minimum of 400 MW in Maryland.

Although many northeastern states have already contracted offshore wind projects and are in the process of contracting more, this is just the beginning of massive pipeline of projects that will be contracted, developed, and built in this decade. Many states have their own offshore wind power commitments stretching to 2030 and beyond. In addition to the 4,580 MW of offshore wind farms already contracted to supply power and the 2,658 under negotiation, contracts are expected to be signed for approximately 17,000 MW of additional projects due to state commitments in the period 2020-2030. Therefore, we forecast there will be 32,352 MW of contracted offshore wind power by 2030.

Collectively, these state commitments are equivalent to the electrical capacity of 32 large nuclear power plants, an extraordinary CAPEX that requires many suppliers. This SIOW report provides an update of the original 2019 analysis of what this massive construction effort means for the offshore wind energy sector, in data broken down year-by-year and by key wind farm component. Specifically, this analysis forecasts:

1) the total quantity of components associated with the ~32 GW of offshore wind projects expected to sign contracts with suppliers from 2020 to 2030; and
2) the value of those supply chain contracts.

Indeed, this pipeline of over 30 GW of offshore wind development could not be realized without the available offshore real estate on which to build and operate our nation's wind farms. The Bureau of Ocean Energy Management (BOEM) has spent the past decade focused on the responsible and expedient leasing of the nation's offshore submerged lands. Without their proactive and progressive approach to lease sales to make the areas off the Atlantic coast available for development, the offshore wind sector would not have the available lands for establishing this over 30 GW pipeline. Additionally, since January of 2021, BOEM has made substantial progress in the permitting of the offshore wind projects in the pipeline. This critical step helps to advance projects to a point where they will realize their full economic potential, including issuing eight Notices of Intent and approving the nation's first utility-scale project, Vineyard Wind.

To date, many supply chain analyses of the future U.S. offshore wind power market have focused on the number of jobs that will be created using three primary metrics: the number of individual wind farms proposed, the size and number of state-level offshore wind commitments, and estimates of the national offshore wind resource potential. This report instead analyzes offshore wind commitments by state to forecast years when states are likely to solicit and procure offshore wind power, focusing on how that activity in influence the private sector supply chain expenditures.

Using this power contract forecast, we analyze what it means for the supply chain in terms of quantities of components and contract value, and when supply chain work packages are likely to be forthcoming. We examine the revenue opportunity of this new industry for the supply chain irrespective of the locale of contract origination, acknowledging that the offshore wind supply chain has local, national, and international participants. This approach provides an analysis on how this industry will unfold, with detail about how much of, and when multiple supply chain components are expected to be contracted.

Note that this analysis predicts the volume and value of components and services needed to develop the committed offshore wind build and is geographically agnostic. Initially, more of the components will come from Europe than from the U.S. We do not predict when or to where the production will shift.

METHODS

The Special Initiative on Offshore Wind worked with The Renewables Consulting Group (RCG) to develop an approach for forecasting the offshore wind power market and forecasting the required supply chain needs and supply chain participation. RCG conducted all analyses reported here. Please see the Appendix for details on the assumptions used in the modeling.

In a previous engagement, RCG provided to SIOW the underlying analysis for the *Supply Chain Contracting Forecast for U.S. Offshore Wind Power*, published in March 2019. This analysis included projections of market demand for offshore wind energy on the U.S. East Coast and the CAPEX associated with this demand. We predicted nearly $70 billion in CAPEX through 2030 associated with a cumulative market demand of 18.6 GW across six states.

In 2021, SIOW contracted RCG to refresh and expand the analysis contained in the March 2019 forecast. The CAPEX analysis has been refreshed to include recent market updates such as state procurement targets as well as updated cost information available for the U.S. offshore wind market. The analysis has also been expanded to include OPEX and DEVEX forecasting to provide a more comprehensive view of the spend that will be required in each year leading to 2030. Data contained in this report were current as of July 2021.

RCG's analysis addresses four research questions:

1. What is the likely scenario for offshore energy contracting between developers and off takers during the period 2020-2030?

2. Given the forecast for power contracting, what quantities of components will be needed, and which years, to build the wind farms now required to meet state commitments?

3. Given the forecast for power contracting and the predicted volume of components that will be needed, what is the total CAPEX – and potential revenue opportunity – that can be expected from these contracts?

4. Given the forecast for power contracting and the predicted volume of components that will be needed, what is the total OPEX and DEVEX that can be expected from these contracts?

Part 1: Offshore Wind Power Contracting Forecast

The research team first compiled the details of wind power in each state, both contracted and in negotiation, for the state's offshore wind commitments and announced power procurement timelines. For states that have made offshore wind commitments but not yet announced a procurement schedule, assumptions for power procurement timelines were made based on their goals and past procurement schedules.

This analysis only includes states with either current procurement processes underway or states where a relevant state department and/or utility has committed to the procurement of offshore wind. For example, North Carolina has not been included in this analysis because the state's legislation indicates that it will "strive" for development of 2.8 GW of offshore wind off the North Carolina coast by 2030 and 8 GW by 2040, but does not commit the state or utilities to procure offshore wind.[2] Additionally, there are other markets that we expect will soon procure offshore wind including states off the Gulf of Maine, states in the Gulf of Mexico, California, and Oregon. These states have not been included in the analysis as they do not have any procurement targets or legislation requiring procurement of offshore wind. However, we expect this will soon change and further increase the expenditures that will be required to meet this growing demand.

An overview of assumptions for each state is listed in Table 6 in the Appendix.

[2] https://files.nc.gov/governor/documents/files/EO218-Advancing-NCs-Economic-Clean-Energy-Future-with-Offshore-Wind.pdf?utm_content=buffer6a389&utm_medium=social&utm_source=linkedin.com&utm_campaign=buffer

The following definitions apply to the categories used in this report.

Contracted:

- A power contract and/or Offshore Renewable Energy Credit (OREC) has been agreed to between the offshore wind developer and the relevant state department and/or utility.

In Negotiation:

- The final terms of a power contract and/or OREC are still to be agreed upon by the offshore wind developer and relevant state department and/or utility.

Bids Under Evaluation:

- The relevant state department and/or utility is in the process of evaluating bids from competing developers to supply electricity from eligible offshore wind projects.

Announced Future Solicitations:

- The relevant state department and/or utility has committed to the procurement of electricity from renewable energy sources, and/or offshore wind specifically, but the bidding window for eligible projects has yet to open.

To forecast the years in which procurements could take place in each state, we used the following information and assumptions. See Table 6 in the appendix for details.

> **Rhode Island** is planning to issue a competitive request for proposals (RFP) to procure up to 600 MW of new offshore wind energy. The RFP is expected to be issued in 2021.[3]
>
> **Connecticut's** Public Act 19-71 requires that Department of Energy and Environmental Protection (DEEP) procure a nameplate capacity of 2,000 MW of offshore wind by 2030. While no formal procurement schedule has been released, the 2020 Draft Integrated Resources Plan calls for a 2023 Class 1 solicitation that includes offshore wind, followed by a second solicitation before the end of the decade. Therefore a 2023 solicitation for 1,000 MW has been assumed.[4]
>
> **Massachusetts** is currently evaluating bids submitted to the Section 83C Round 3 solicitation process/RFP**.** The state plans to announce the winners of the solicitation in December 2021**.** Massachusetts will need to procure an additional 2,400 MW of offshore wind energy by 2027.[5]
>
> In **New York**, under current conditions, it takes approximately one year to approve an order from the state's Public Service Commission before running a procurement process. Based on this, we have assumed that a procurement process could take place every year or every other year in New York. Considering this assumption, and the size of recent procurements in the state, our forecast indicates New York will procure approximately 9,000 MW by 2030.
>
> The forecast for **New Jersey** procurements is taken from the New Jersey Board of Public Utilities offshore wind procurement schedule.[6]
>
> The **Maryland** forecast assumes the schedule set forward in the Clean Energy Jobs Act passed in 2019.
>
> The **Virginia** forecast assumes the state will contract projects to reach its 5,200 MW target in 1 GW increments every 2 years after an initial larger procurement of 2,600 MW in 2022.

The assumptions above are reflected in the forecasts in Table 1, which are categorized in decreasing levels of certainty, the least certain being the quantities

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3 https://www.offshorewind.biz/2020/10/28/rhode-island-to-issue-600-mw-offshore-wind-call/

4 https://portal.ct.gov/-/media/DEEP/energy/IRP/2020-IRP/2020-CT-DEEP-Draft-Integrated-Resources-Plan-in-Accordance-with-CGS-16a-3a.pdf, p 151.

5 https://www.mass.gov/news/governor-baker-signs-climate-legislation-to-reduce-greenhouse-gas-emissions-protect-environmental-justice-communities

6 https://myemail.constantcontact.com/NJBPU-Publishes-Revised-Offshore-Wind-Solicitation-Schedule.html?soid=1102115586534&aid=Gv_OicwWiW0

required in the future by state policy, which is subject to ever-changing political conditions.

Table 1: Offshore Wind Power Contracts Forecast by Category (2016 – 2030)

Category	Solicitations (Including Size and State)
Contracted	400 MW – RI 304 MW – CT 804 MW – CT 800 MW – MA 804 MW – MA 1,100 MW – NJ 4,314 MW – NY 368 MW – MD 12 MW – VA
In Negotiation	2,658 MW – NJ
Bids Under Evaluation	1,600 MW – MA 400 MW – MD
Announced Future Solicitations	1,000 MW – CT 2,400 MW – MA 3,800 MW – NJ 5,000 MW – NY 800 MW – MD 5,200 MW – VA 600 MW – RI

Part 2: Supply Chain Contracting Forecast – Quantities

The analysis considered all currently leased BOEM areas and the lease areas in the New York Bight that are scheduled to be auctioned to developers in the Fall of 2021. In the project-specific models, procurement volumes attributed to each lease area are lower or equal to the lease area's technical capacity. Table 2 illustrates the components and units considered.

Table 2: Components Considered in the Analysis

Components Considered	Unit
Array Cables	Kilometers
Export Cables	Kilometers
Foundations	Number
Offshore Substations (OSS) Foundations	Number
Offshore Substation (OSS) Topsides	Number
Wind Turbine Generators (WTGs)	Number

RCG's Global Renewable Infrastructure Projects database (GRIP) contains information on when each project will begin its supply chain procurement process for the components listed in Table 2 above.

GRIP stores publicly available information relating to 1,000+ existing and planned offshore wind projects, with worldwide coverage. Project milestones in GRIP are based on offshore wind project data that is correlated with market specifics, project size, and technology. For the US, an indicative schedule that estimates the time for leasing, site assessment, offtake, permitting, financing, contracting, installation, and commissioning is used. However, the schedule of each project varies slightly based on BOEM's permitting schedule, status of offtake agreement, and project-specific delays. For example, projects that win Power Purchase Agreements (PPAs) prior to having completed their Construction and Operations Plan (COP) and permitting process will have a longer delay between power contract award and procurement, while projects who win a power contract while they are far along in their COP approval process will have a shorter gap between power contract and procurement.

The forecast is also based on turbine-size assumptions. Wind-turbine size impacts the number of turbines, foundations, and array cable length required to install a given project capacity (in MW). To consider future technological advances in turbine design, different rated capacities for the turbines were assumed for power procured in different years. Actual turbine sizes were used where applicable. For projects that have not publicly announced the turbine size they plan to use, assumptions were made ranging from 15 to 19 MW turbines. Detailed assumptions on turbine sizes are presented in the Appendix, alongside assumptions around maximum substation capacity and the length of cables.

Part 3: Supply Chain Contracting Forecast – CAPEX, OPEX and DEVEX

The cost estimates in this analysis are underpinned by RCG's GRIP 2.0 project database and cost forecasting tool. GRIP leverages RCG's experience forecasting costs and levelized cost of energy (LCOE) for offshore wind projects globally. GRIP 2.0 pairs cost algorithms constructed using knowledge from more than 25 U.S. and global offshore wind farms with specific project data and site conditions for each of the project areas developed through 2030.

This analysis forecasts CAPEX, OPEX, and DEVEX for each project independently. Each cost item was then sense-checked for alignment with offshore wind benchmark values available in the U.S. market. The cost schedules consider the development, construction, and operational timeline for each project independently, consolidating all package costs across each project for a given year. Investment timelines are aligned to the expected financial close for each project, with construction schedules dependent on project size. Larger projects assume a longer construction schedule due to the number of installation days required while smaller projects will assume a shorter overall construction schedule.

Because each project's costs are assessed independently, site-specific cost adjustments were applied to account for the market and technology trends likely to be key determinants of the landscape at the commercial operations date. As such, the cost estimates consider project design and environmental conditions, as well as global technology advancements and supply chain maturity expected in the region.

FINDINGS

Part 1: Offshore Wind Power Contracting Forecast

At the time of this report's release, over 8,000 MW of offshore wind farms were under contract in Connecticut, Maryland, Massachusetts, New York, New Jersey, Rhode Island, and Virginia. Both the Atlantic Shores project and Ocean Wind 2 project were deemed as Qualified Offshore Wind Projects to receive ORECs. Massachusetts and Maryland are both reviewing bids they received in response to their latest solicitations. In total, there are currently 13.5 GW of offshore wind contracted, in negotiation, and under evaluation.

The analysis of additional procurements required by state policy and future expected procurements lead us to forecast a total of 32,352 MW of offshore wind procured by 2030. Table 3 details our state-by-state, year-by-year forecast for offshore wind power contracting.

Table 3:
Offshore Wind Power Contracts (in MW) Forecast by State

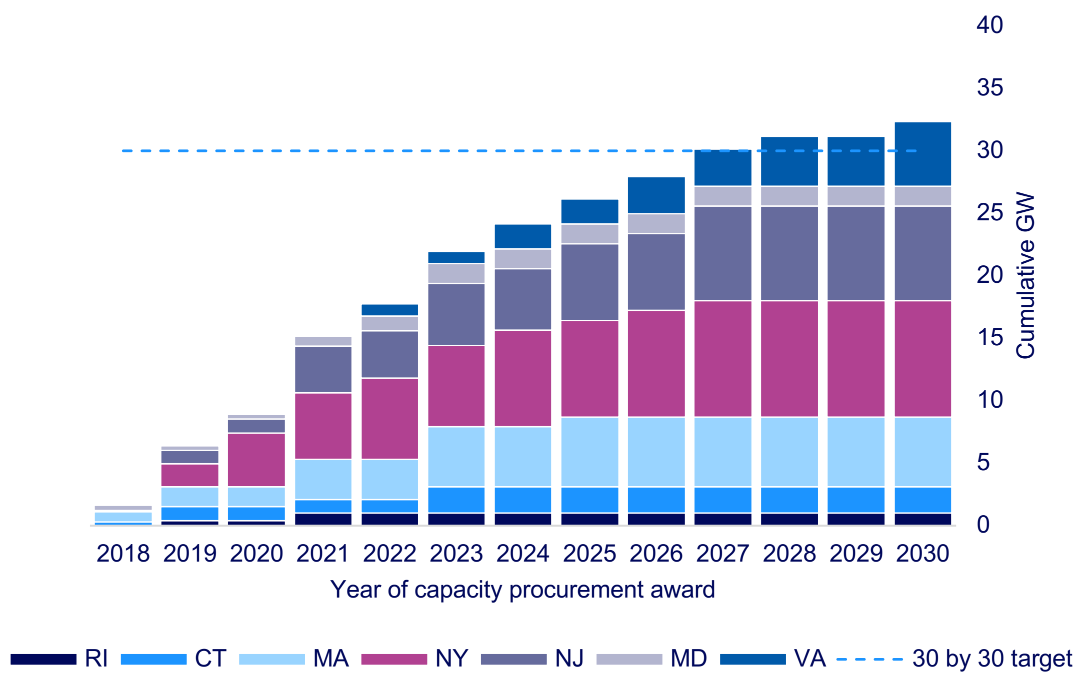
Year	RI	CT	MA	NY	NJ	MD	VA
2018		304	800	128		368	
2019	400	804	804	1,696	1,100		
2020				2,490			
2021	600		1,600		2,658	400	
2022				1,200		400	2,600
2023		1,000	1,600	1,000	1,200	400	
2024				1,200			1,000
2025			800		1,200		
2026				800			1,600
2027				800	1,400		
2028							
2029							
2030							

Figure 3 illustrates the cumulative predicted growth in offshore wind power procurements. As it indicates, we forecast that offshore wind power contracts in Connecticut, Massachusetts, New Jersey, New York, and Rhode Island will be signed during 2020-2022, representing an additional 5,500 MW of capacity.

In the years 2022-2025, we expect to see 6,432 MW contracted, with large procurements happening especially in New York and New Jersey, which both have large offshore wind commitments to meet.

Increases in offshore wind procurement from the years 2025-2030 will result from New York, Maryland, and Connecticut continuing to meet their current targets for offshore wind power as well as Renewable Portfolio Standard (RPS) or other renewables mandates.

Figure 3:
Offshore Wind Power Contracts Forecast 2018 – 2030



Part 2: Supply Chain Contracting Forecast – Quantities

Table 4 shows the total quantity of components expected to be contracted by 2030, for each key component, to meet the procurement volumes expected in the various states.

It should be noted that the quantities estimated in this report only reflect the quantities procured by the 32 GW of projects that will be procured between 2020-2030. Construction and operation of these projects will continue past 2030 and therefore, spending will also continue.

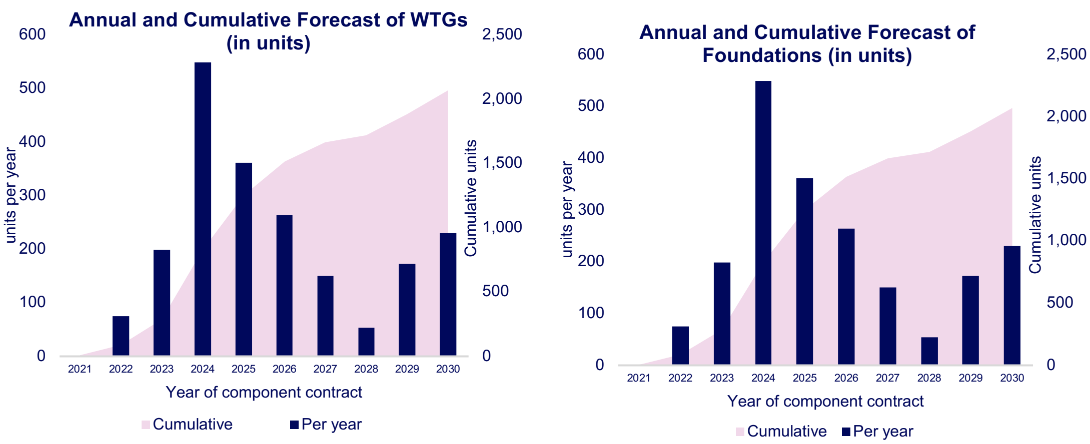
Although total procured volume by 2030 reaches 32,352 MW, only component contracts executed through 2030 are depicted in the analysis.

Table 4:
Estimated Quantities of Components Required by 2030

	Estimated Quantities
WTGs	2,057
Foundations	2,057
Array Cables (km)	5,381 km
Export Cables (km)	5,463 km
Offshore Substation Topsides	53
Offshore Substation Foundations	53

Figures 4 through 6 show the estimated quantity of each key component that will be needed over the course of the build-out.

Figure 4: Turbine and Foundations Quantities Forecast



An estimated 2,057 wind turbine generators (WTGs) will be contracted for installation in U.S. waters between now and 2030 for the projects procured between 2018 and 2028 (and therefore contracted from 2020 through 2030). Contracts for WTGs will begin in earnest at the beginning of the 2020s. The bulk of contracts will be executed by 2027 but will continue until the end of the decade. On average, 241 WTGs are likely to be contracted each year between 2020 and 2026.

After 2026, only 152 are likely to be needed per year, although this reduction is due in part to the fact that the turbines are expected to be much larger than those currently on the market today (see Appendix for assumptions around turbine size in this analysis) hence reducing the number of turbines needed rather than simply a reduction in demand in terms of MW.[7] This reduction is also partly due to the declining amount of market visibility beyond 2026. New states are likely to enter the market in the coming years and will extend the progression of continued increases in WTGs needed to meet demand.

Lastly, it is estimated that 2,110 foundations, for both WTGs and offshore substations, will be contracted by 2030. Foundation procurement largely tracks that of WTGs. The number of foundations ordered will temporarily decline through the late 2020s due both to project schedules and to the expected increase in turbine sizes.

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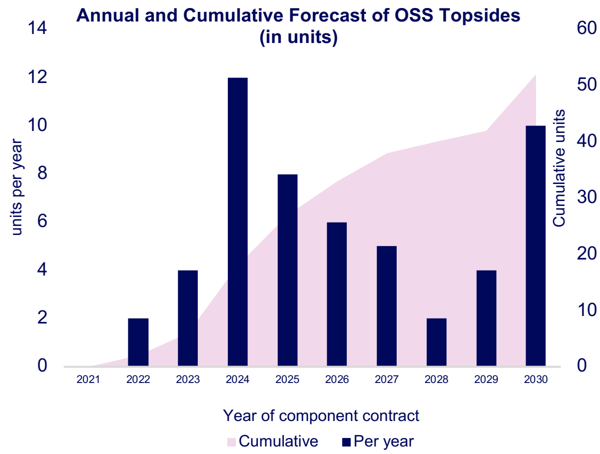
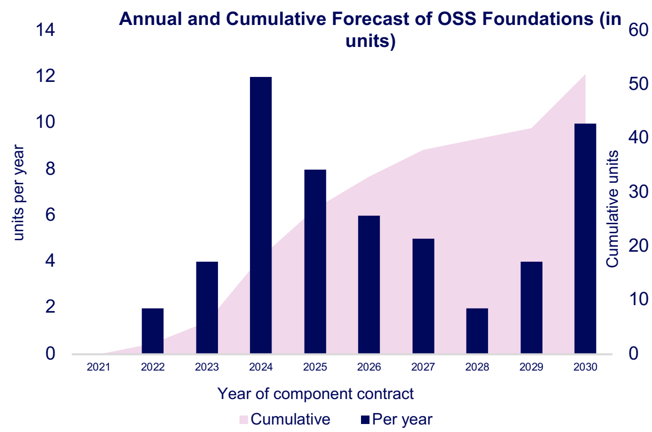
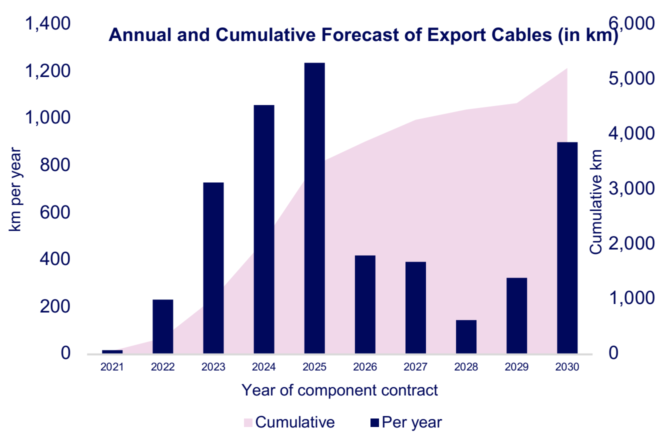
[7] This is for the time period 2020-2030. Additional procurement is expected from the states beyond 2030.

Figure 5: Offshore Transmission Components Quantities Forecast



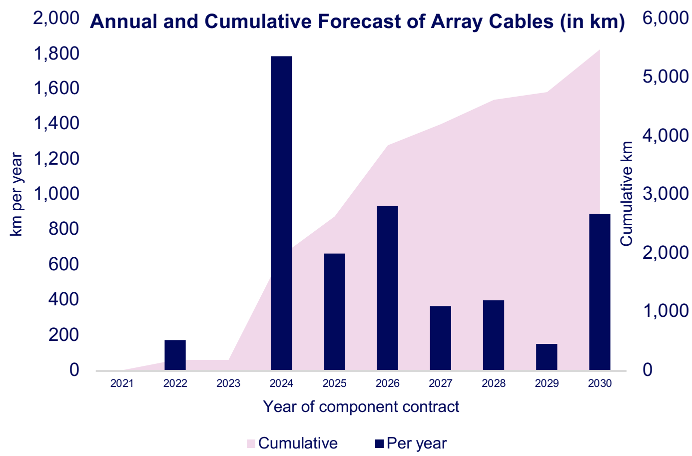




In total, it is estimated that 53 offshore substations will be contracted by 2030 with an average of more than five substations per year. The rate of increase is higher in the first half of the decade, slowing down after 2025 as many projects move from procurement into construction.

As estimated 5,463 km of export cable will be contracted by 2030. There will be substantial demand starting in 2022 and continuing throughout the build-out, with major increases in demand year on year through 2025 and again in 2030. The annual export cable length required is much more variable than any other components, with the bulk contracted in the first year. Likewise, the total length of export cable is highly sensitive to factors such as the choice of landfall (and therefore the cable route), size of the project, alternating versus direct current, and voltage of the equipment.[8]

Figure 6: Array Cable Length Forecast



Approximately 5,381 km of array cables are forecasted to be contracted by 2030. The demand for array cable contracts will therefore average more than 500 km a year.

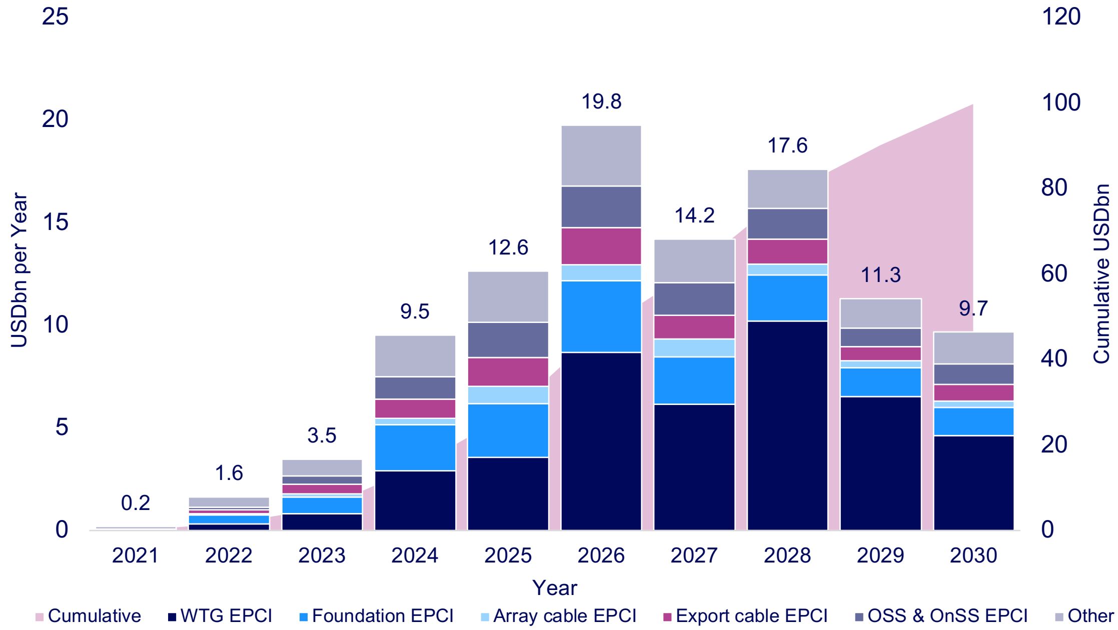
Part 3: Supply Chain Contracting Forecast – CAPEX, OPEX, and DEVEX

We estimated CAPEX associated with the engineering, procurement, construction, and installation (EPCI) contracts of the seven components quantified above. An EPCI contract bundles manufacture and installation of the component into one cost and therefore includes vessel costs. In addition to these components, “other” costs were included to account for additional marine support, insurance, and project management.

Figure 7 illustrates total estimated cumulative CAPEX associated with component contracts signed between 2020 and 2030. As explained in Part 2, this forecast only accounts for the spending associated with the 32 GW of projects procured before 2030. Many of these projects will continue to procure not only CAPEX but much of their OPEX spend as the projects continue operations into the 2030s. Additionally, projects not included in the 32 GW pipeline that begin development by 2030 may begin to contribute further spending.

[8] Where project interconnection points and cable routes were unknown, a high-level GIS analysis was carried out to estimate the most likely cable route and point of interconnection.

Figure 7: Offshore Wind Supply Chain Contracts Cumulative CAPEX Forecast



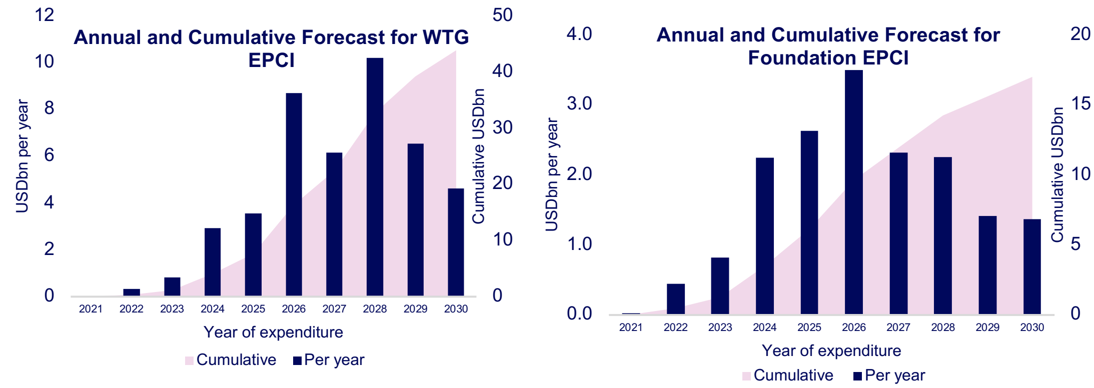
Specifically, Figure 7 illustrates that the primary drivers of offshore wind CAPEX – and therefore the largest value contracts – will be, in order of magnitude:

- Wind Turbine Generator EPCI
- Foundation EPCI
- Offshore and Onshore Substation EPCI

A smaller proportion of CAPEX is the export and array cable contracts and contracts for contingency, project management, insurance, legal and financing fees, contracting costs, and other miscellaneous project costs. Figure 8 also illustrates that these spending and activity levels are rather constant on an annual basis throughout the years 2024-2030. That is, contrary to some prognostications, we do not predict an extreme boom/bust cycle for any of the key components; rather, we predict a steady CAPEX expenditure on these components.

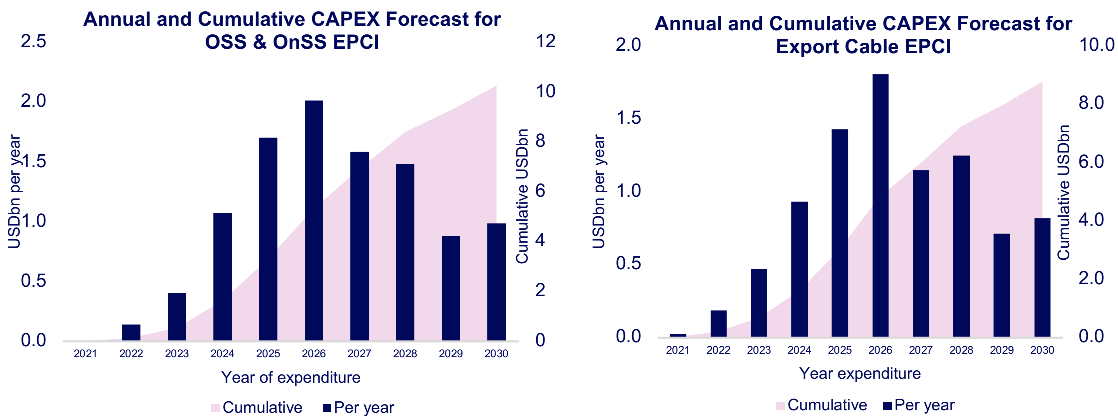
Figures 8 through 12 below display the expected cost associated with the annual procurement volumes, for each key component, over the course of the build-out.

Figure 8: Turbine and Foundation Components CAPEX Forecast



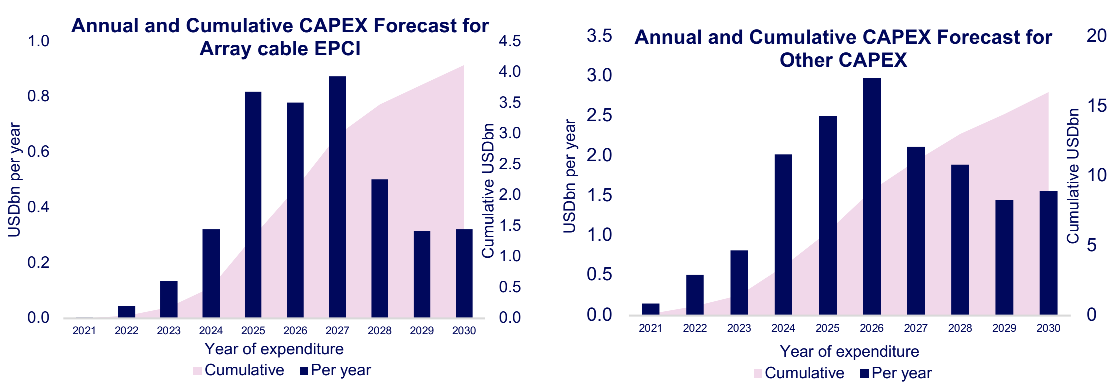
The major driver of CAPEX is the turbine followed by the foundation. Total WTG expenditure for U.S. projects is expected to reach $44 billion between 2020 and 2030, more than double that of foundations, which are expected to bring revenues of $17 billion. The turbine market will increase substantially between now until the end of the decade with peak spending years occurring in 2026 and 2028. The foundation market will see a similar differential between the first and the second half of the decade, with an average annual expenditure of $1.2 billion increasing to about $2.1 billion after 2025.

Figure 9: Offshore Transmission Components CAPEX Forecast



The offshore and onshore substation market is expected to be worth $10.3 billion from 2020-2030, while the export cable market will bring revenues of approximately $8.3 billion over the same period. On an annual basis, expenditure associated with offshore and onshore substations will average $660 million between 2021 and through 2025. This will increase to an average of about $1.4 billion in the second half of the decade. The expenditure for export cables is expected to average about $608 million a year in the first half of the decade, followed by an increase to a $1.1 billion annual expenditure after 2025.

Figure 10: Array Cable and 'Other' CAPEX Forecast



Finally, the array cable market is expected to be $4.1 billion from 2020-2030. On average this represents an investment of $260 million a year from 2021 through 2025. This investment will increase to about $560 million a year on average thereafter. All other elements of CAPEX including contingency, project management, insurance, legal and financing fees, contracting costs, and other miscellaneous project costs are expected to be worth about $16 billion by 2030 for an annual average of almost $1.6 billion a year.

Table 5 presents the expected cumulative value of contracts for the various components. The potential value flowing to offshore wind energy suppliers across the components in the period 2020-2030 is over $100 billion.

Table 5: Estimated Cumulative CAPEX by Component Type

	Estimated CAPEX by 2030
Onshore and Offshore substation EPCI	$10.3 bn
Export and Array cable EPCI	$12.9 bn
Foundation EPCI	$17.0 bn
WTG EPCI	$43.9 bn
Other (insurance, marine support, PM)	$16.0 bn
Total CAPEX	**$100.1 bn**

Figure 11: Offshore Wind Cumulative and Annual DEVEX Activity

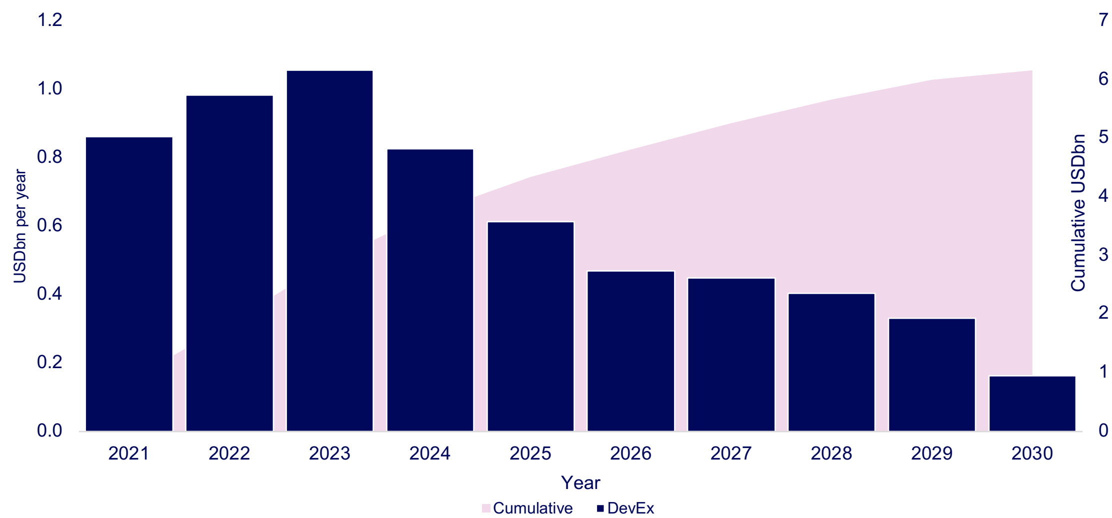


Figure 11 illustrates the total estimated DEVEX associated with projects in development and construction between 2018-2030. For the projects solicited through 2030, DEVEX investments will primarily occur during the first half of the 2020s, reaching a total of nearly $6 billion by 2030.

Figure 12: Offshore Wind Cumulative and Annual OPEX Activity

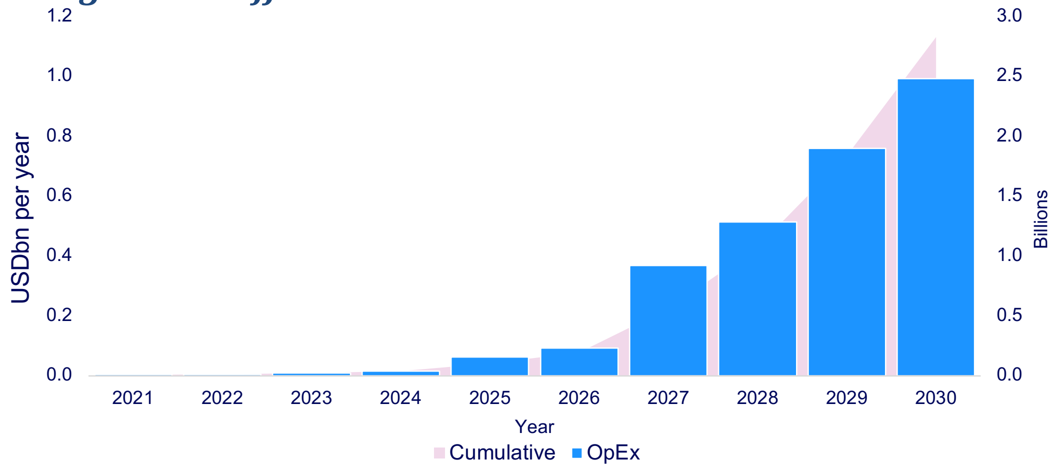


Figure 12 illustrates estimated OPEX associated with projects in operation between 2018 and 2030. As explained in Part 2, this forecast only accounts for the spending associated with the 32 GW of project that will take place before 2030. These projects will increase their OPEX spend as the projects continue their operation into the 2030s. Conversely to DEVEX, OPEX investments scale up steadily as more and more projects reach operation by 2030. OPEX levels will continue to rise as all projects solicited by 2030 reach operation, and they will remain high through the 25-to-35-year lifetimes for each project.

CONCLUSIONS

This study forecasts a nearly $109 billion revenue opportunity for U.S. offshore wind component suppliers through the end of the coming decade and highlights this sector's critical inflection point. The offshore wind supply chain remains largely global, with a growing number of U.S. offshore energy and onshore wind suppliers preparing to enter the industry. Many of the supply chain actors, both international and domestic, are grappling with the questions of whether, when, and where to set up manufacturing hubs in the U.S.

For states with offshore wind power commitments, this forecast is also a quantification of the enormous quantities and value of components needed, especially early in the build-out. Moreover, as states work to attract supply chain facilities, the forecast clarifies the enormous volume of necessary components. These data may help guide the pace of offshore wind infrastructure development and the timing of supply chain incentives.

Many states have made, or are predicted to make, significant offshore wind power procurement commitments; other states will be procuring incrementally to help meet their RPS targets. The procurement schedule forecasted here suggests that, when offshore wind power contracting slows down in one state, the momentum will continue in other states and continue to drive the supply chain potential of this massive and growing industry.

APPENDIX

Assumptions

Procurement Volumes

Table 6: Assumptions for States' Procurements

State	Contracted	In Negotiation	Bids Under Evaluation	Announced Future Solicitations
Connecticut	Connecticut PUC approved the 200 MW Revolution Wind project's PPA with Eversource Energy and United Illuminating Co. and another 100 MW from Revolution Wind.[9] The PUC also approved the 804 MW Park City Wind project's PPA with Eversource Energy and United Illuminating.[10]			In June 2019, Connecticut enacted a law requiring the state to procure 2,000 MW of offshore wind by 2030.[11] No timeline has officially been announced however DEEP's IRP (Integrated Resource Plan) recommended a Class 1 RFP that includes offshore wind in 2023.[12]
Maryland	Public Service Commission approved two offshore wind projects totaling 368 MW in May 2017, allowing the developers to receive ORECs.[13]		Maryland opened its second offshore wind solicitation in 2020 and results are expected to be announced in 2021.[14] [15]	In May 2019, Maryland passed an offshore wind mandate for an additional 1,200 MW by 2030.[16]

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9 https://orsted.com/en/media/newsroom/news/2018/12/connecticut-regulators-approve-revolution-wind-power-contract

10 https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12782057

11 https://www.cga.ct.gov/2019/amd/H/pdf/2019HB-07156-R00HA-AMD.pdf

12 https://portal.ct.gov/-/media/DEEP/energy/IRP/2020-IRP/2020-CT-DEEP-Draft-Integrated-Resources-Plan-in-Accordance-with-CGS-16a-3a.pdf

13 https://www.psc.state.md.us/wp-content/uploads/PSC-Awards-ORECs-to-US-Wind-Skipjack.pdf

14 https://mdoffshorewindapp.com/sites/default/files/public/MD%20PSC%20Offshore%20Wind%20Technical%20Conference%20April%2021%202020.pdf

15 https://mgaleg.maryland.gov/2019RS/fnotes/bil_0006/sb0516.pdf

16 https://mgaleg.maryland.gov/2019RS/fnotes/bil_0006/sb0516.pdf, see footnote 3.

Massachusetts	The Massachusetts DPU approved 800 MW Vineyard Wind's PPA and the 804 MW Mayflower Wind's PPA with the MA Distribution Companies.[17]		Massachusetts opened its third solicitation in May of 2021 and is expected to announce results in December of 2021.[18]	Massachusetts passed legislation authorizing utilities to procure 5600 MW of offshore wind by 2027.[19]
New Jersey	The NJ BPU granted the 1,100 MW Ocean Wind project ORECs in 2019.[20]	In 2020, New Jersey opened its second solicitation and the BPU awarded 1,510 of capacity to the Atlantic Shores project and 1,148 MW of capacity to the Ocean Wind II project.[21]		New Jersey has committed to procure 7,500 MW by 2035.[22] The BPU's announced schedule includes: 1200 MW awarded in 2023, 1200 awarded in 2025, 1,342 MW awarded in 2027.[23]
New York	LIPA signed a PPA for the 90 MW South Fork Wind Farm in 2017 and agreed to buy an additional 40 MW in 2018.[24] In 2019, NYSERDA signed an OREC for 816 MW (Empire Wind) and 880 MW (Sunrise Wind).[25] In 2021, NYSERDA signed an OREC with the 1,260 MW Empire Wind 2 and the 1,230 MW Beacon Wind 1 project.[26]			New York made a commitment to procure 9,000 MW by 2035.[27]

17 https://www.mass.gov/news/department-of-public-utilities-approves-offshore-wind-energy-contracts-0

18 https://macleanenergy.com/83c-iii-timeline/

19 https://macleanenergy.com/author/cleanenergyrfp/

20 https://www.bpu.state.nj.us/bpu/newsroom/2019/approved/20190621.html

21 https://www.nj.gov/bpu/pdf/OSWFactSheets_Final_630.pdf

22 https://www.nj.gov/bpu/pdf/OSWFactSheets_Final_630.pdf

23 https://www.njcleanenergy.com/renewable-energy/programs/nj-offshore-wind/solicitations

24 https://www.lipower.org/wp-content/uploads/2019/10/LIPA-First-Offshore-Wind-Farm-Doc-V19_102819-FINAL.pdf

25 https://www.nyserda.ny.gov/About/Newsroom/2019-Announcements/2019-10-23-Governor-Cuomo-Announces-Finalized-Contracts-for-Empire-Wind-and-Sunrise-Wind-Offshore-Wind-Projects

26 https://www.nyserda.ny.gov/All%20Programs/Programs/Offshore%20Wind/Focus%20Areas/Offshore%20Wind%20Solicitations/2020%20Solicitation

27 https://www.nyserda.ny.gov/all-programs/programs/offshore-wind

Rhode Island	National Grid signed a PPA for the 400 MW Revolution Wind project in 2018.[28]			
Virginia				In 2020, the state legislature passed the Virginia Clean Economy Act, which set a 100% renewable energy goal by 2050 and set an offshore wind procurement goal of 5,200 MW by 2035.[29]

Component Quantities

The following assumptions were made in the market demand modeling. Where ranges were derived, median values were used.

Onshore Substations (units)

- One onshore substation per project.

Onshore Cable (km)

- Length (km): Upland cable routes were measured via GIS and/or approximated from a map scale, for each project from the most likely landfall site to most likely connection point and multiplied by the assumed number of cables.
- Number of cables: One circuit is assumed for each offshore substation.

Export Cable (km)

- Length (km): Subsea export cable routes were measured via GIS and/or approximated from a map scale, for each project to the most likely landfall site and multiplied by the assumed number of cables. Additionally, 15 km of inter link cable was assumed for each additional substation required on projects >400 MW in size.
- Number of cables: one HVAC cable for each offshore substation assumed.

28 https://us.orsted.com/news-archive/2019/05/rhode-island-regulators-approve-revolution-wind-power-contract

29 https://lis.virginia.gov/cgi-bin/legp604.exe?201+sum+HB1526

Array Cable (km)

- Using RCG's array cable length model, a ratio of km/MW for each range of turbine sizes was derived using an estimated power density for each lease area.
- The inputs to the model include, but are not limited to, turbine size, area, density, and number of substations.

Offshore Substations (units)

- One offshore substation per 400-500 MW AC circuit, and one offshore substation per DC system.

Wind Turbines (units)

- Actual/announced turbine sizes were used where applicable. For projects that have not publicly announced the turbine size they plan to use, the following assumptions were made:
    - 15 MW turbine for projects with an expected operational date between 2026 and 2027
    - 17 MW turbine for projects with an estimated operational date between 2028 and 2029
    - 19 MW turbine for a project with an estimated operational date of 2030 and beyond

Foundations (units)

- One foundation per turbine and one foundation per conventional offshore substation.

Note: For projects that have published publicly available information or have COPs that are currently under review by BOEM and are in the public domain, RCG has utilized the specified statistics regarding the project for component quantity assumptions.

Cost Estimates

Assumptions and exclusions that underpin cost estimates include:

- Figures are all quoted in 2021 real dollars.

- The total estimated CAPEX, OPEX, and DEVEX is associated with component contracts signed between the years 2020 and 2030. The estimates are based on supply chain contracts executed through 2030.

- The total estimated TOTEX does not include decommissioning spend as there is no planned decommissioning activity between 2020 and 2030. However, the market will see decommissioning spend in later years as the installed projects reach end of life.

- Cost trends do not include any raw material tariffs, commodities price forecasts, or future exchange rates to underpin the numbers.

- Estimates exclude grid upgrade costs onshore, interconnection fees, lease acquisition costs, investments in local fabrication facilities and port infrastructure projects, or any operating lease or grid fees.

- Cost estimates assume radial transmission system and not a shared transmission system.